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# Electrical Engineering in Los Alamos Neutron Science Center Accelerator

By: Michael Silva

The field of electrical engineering plays a significant role in particle accelerator design and operations. Los Alamos National Laboratories LANSCE facility utilizes the electrical energy concepts of power distribution, plasma generation, radio frequency energy, electrostatic acceleration, signals and diagnostics. The culmination of these fields produces a machine of incredible potential with uses such as isotope production, neutron spallation, neutron imaging and particle analysis. The key isotope produced in LANSCE isotope production facility is Strontium-82 which is utilized for medical uses such as cancer treatment and positron emission tomography also known as PET scans. Neutron spallation is one of the very few methods used to produce neutrons for scientific research the other methods are natural decay of transuranic elements from nuclear reactors. Accelerator produce neutrons by accelerating charged particles into neutron dense elements such as tungsten imparting a neutral particle with kinetic energy, this has the benefit of producing a large number of neutrons as well as minimizing the waste generated. Utilizing the accelerator scientist can gain an understanding of how various particles behave and interact with matter to better understand the natural laws of physics and the universe around us.

The Los Alamos Neutron Science Center is one of the largest electrical power demand in the state of New Mexico. A significant amount of power is necessary to supply electrical energy to the various magnets, pumps, RF amplifiers, HVAC units and instrumentation for the 24 hour facility. LANSCE gets its primary source of power from the Four Corners Generating plant in Fruitland, New Mexico. In order to accommodate for the drop in voltage across transmission lines from the Four Corners plant to LANSCE the power plant must utilize a step up transformer to raise voltage to approximately 115 kV. The transformer accomplishes this by electrical transformer theory where a conductor wound around a permeable core will induce a voltage in a secondary conductor wound across the same core, the output of the transformer is dependant on the ratio of windings from the primary conductor to the secondary conductor. This permits raising voltage to higher levels which has two advantages, a fault on one side of the transformer electrically isolates the others side and because power is the product of voltage and current as voltage is increased current must have a corresponding decrease. The decrease in current reduces the  $I^2R$  losses across the transmission lines. From the power plant power is fed into LANSCE via two overhead transmission cables at 115 kV and distributed to the facility's electrical distribution system with tie breakers connecting busses in parallel and load distribution breakers isolating the various loads in the system. The two transmission lines are there for redundancy purposes in the event that power is lost on one of the lines power can be retained to the facility by the other transmission line.

Plasma is the fourth state of matter and occurs when a gas is superheated thus creates a cloud of charged particles and kinetic energy with heat as a byproduct. Fire or airborne electrical current are the most common forms of plasma found in nature. LANSCE produces two forms of plasma from hydrogen gas affectionately called "H+" and "H-". H+ is created by pumping hydrogen gas into a small container known as the H+ source and utilizing a highly charged anode

and cathode to separate hydrogen's electron from the proton, the proton is ejected from the source into the accelerator piping by the highly charged anode,  $H^+$  leaves the source at approximately 80 keV.  $H^-$  is a little trickier to generate and is produced utilizing a device called a duoplasmatron. Hydrogen gas is pumped into the duoplasmatron where it is once again exposed to a highly charged anode and cathode but in addition to the hydrogen inserted into the source current is run through a Cesium filament in the source producing a cloud of free electrons in the duoplasmatron. This atomized Cesium coats the cathode and the coating provides an additional purpose once the hydrogen atom is ionized. The highly charged anodes and cathodes separate the electron from the charged particle and the positively charged ion accelerates towards the coated cathode. The positively charged hydrogen ion impacts the cathodes Cesium coating and sputters two electrons onto the hydrogen ion. The now negatively charged hydrogen atom accelerates away from the cathode into its own accelerator piping. There are two key concepts that need to be understood when it comes to plasma use in an accelerator these concepts are the electric field and the magnetic field. These two fields travel together however operate on separate planes by about 90 degrees. The electric field interacts with other electric fields to accelerate or decelerate the charged particles while electromagnets along the accelerator interact with the magnetic field of the charged particles to redirect or steer the particles along the beam line without losing energy.

Electrical energy has an incredibly useful property when produced at a range of frequencies from 3 kHz to approximately 300 GHz. At these frequencies energy is emitted from the conductor in the form of Radio Waves which are electromagnetic waves that are capable of traveling in the air. Most commonly these transmitters are utilized to send information over long distances to a receiver. LANSCE utilizes transmitters called diacodes which operate at 201.25 MHz and Klystrons which operate at four times the diacodes frequency of 805 MHz. These transmitters produce a powerful RF signal that travels along a waveguide into the beam line cavities. The cavities receive the RF and provide a space for an electric field to be induced, this field is along the beam line from upstream to downstream and once the charged particles from the plasma enter this cavity they are accelerated down the beam line via electrostatic interactions of like charges. This process is repeated approximately 48 times to produce a plasma traveling near the speed of light at approximately 800 MeV. The reason that the accelerator operates at two different frequencies is a result of the acceleration process. As a particle accelerates it spends less and less time inside the cavities meaning that in order to achieve the same magnitude of acceleration the cavities will have to get progressively longer. In order to get a particle to 800 MeV utilizing 201.25 Hz the accelerator would have to be several miles long, logistically this would require a significant more land, money and equipment. The alternative to using longer tanks at 201.25 Hz was utilizing smaller cavities that induced an electric field at a much more rapid repetition rate. Thus by multiplying the frequency of the RF field by a factor of four the acceleration cavities can be reduced by a factor of four.

It is very difficult to manage a facility as large as LANSCE without a means of identifying beam conditions standardizing what is normal and recognizing any deviations from those standards. As the plasma accelerates down the accelerator it is required to make several turns down various paths to its designated destination. As stated before the beam is turned using magnetic fields produced by electromagnets along the beam path. The magnitude of beam deflection is proportional to the product of the magnetic field of the charged particle and the field produced by the electromagnets. Therefore because the charged particle does not change magnitude its magnetic field does not change and the deflection of the beam is dependant on the strength of the electromagnets magnetic field. As a byproduct of the various turns and adjustments from the magnetic fields it is often difficult to determine the position of the beam in the accelerator. To assist in determining the position two different diagnostic methods are determined, wire scanners and beam position monitoring. Wire scanners operate by running a small conductive wire across the beam path. As the wire touches the edges of the beam the particles have a path to ground and the instrument indicates a current. The wire moves into the denser regions of the beam producing a proportional increase in current. Therefore it was possible to determine the position of the beam by analyzing the current produced in the wire as it scrapes across the beam. Beam position monitoring operates by placing four plates around the pipe at the 0, 90, 180 and 270 degree positions and connecting them to ground potential. As a packet of charged particles comes between the plates a capacitive effect is felt on the plates and the capacitance is utilized to determine the position of the beam.

In conclusion electrical engineering has a wide array of possibilities and uses and can most often be used in conjunction with each other. The Los Alamos Neutron Science Center accelerator facility is one example where electrical engineers with different areas of expertise can come together and create a machine with the potential that LANSCE has. Operating LANSCE requires not only the fundamental knowledge of electrical theory but also a sampling of some of the more focused areas of the electrical engineering field. Areas of focus that including plasma generation and manipulation, power distribution and Radio Frequency cavity theory. The common underlying factor to all electrical engineering fields is that electrical energy is incredibly dangerous and not only should it be understood but it must also be respected, once that mindset is established electrical energy can provide a benefit to society as well as mankind.

## References:

LANL Safety Assessment Document For the Los Alamos Neutron Science Center (LANSCE)  
User Facility; LANSCE Facility operations

<http://lansceops.lanl.gov/images/ta53/PowerDst.jpg>